

Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance

WHITE PAPER



Bourns® Metal Oxide Varistors (MOVs)



Bourns® Gas Discharge Tubes (GDTs)



Bourns® GMOV™ Components



Bourns® IsoMOV™ Hybrid Protectors



INTRODUCTION

Metal oxide varistors (MOVs) are widely used for surge protection on the Alternating Current (AC) mains ports of electronic products. They are also commonly used in external surge protectors intended for use on the AC mains. MOVs have been a popular surge protection solution for many years due to their low cost and their ability to handle large surge currents.

The UL/IEC 62368-1 standard for Audio/Video, Information Technology and Communication Equipment is a new product-safety standard update, which affects MOV compliance. An excerpt of the UL/IEC 62368-1 standard states:

This part of IEC 62368 is applicable to the safety of electrical and electronic equipment within the field of audio, video, information and communication technology, and business and office machines with a rated voltage not exceeding 600 V. This standard does not include requirements for performance or functional characteristics of equipment.

NOTE 1 Examples of equipment within the scope of this standard are given in Annex a.

NOTE 2 A RATED VOLTAGE of 600 V is considered to include equipment rated 400/690 V.

This part of IEC 62368 is also applicable to: components and subassemblies intended for incorporation in this equipment. Such components and subassemblies need not comply with every requirement of the standard, provided that the complete equipment, incorporating such components and subassemblies, does comply; external power supply units intended to supply other equipment within the scope of this part of IEC 62368; accessories intended to be used with equipment within the scope of this part of IEC 62368.

This part of IEC 62368 does not apply to power supply systems which are not an integral part of the equipment, such as motor-generator sets, battery backup systems and distribution transformers.

The new MOV requirements to meet UL/IEC 62368-1 are now more challenging. Earlier MOV requirements based on IEC 60950-1 will no longer be adequate for product-safety compliance. And to add to the challenge, many designers have noted some confusion due to the wording in the new Annex G.8 requirements for MOVs. The intent of this paper is to try to clear up this confusion. It will also present how various Bourns® MOV, GMOV™, IsoMOV™ Hybrid Protection Components and Gas Discharge Tube (GDT) products help design engineers comply with the updated standard.

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WHAT IS AN MOV?

Metal Oxide Varistors (MOVs) are bidirectional and non-linear surge suppressor components that are widely used for limiting voltage during a surge or transient event in a broad variety of applications. Because an MOV is a non-linear component its characteristics will not vary gradually, but instead will change suddenly when the voltage reaches or exceeds the rated threshold (see Figure 1).

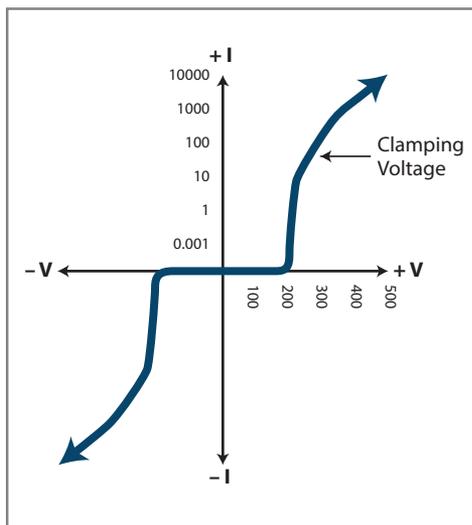


Figure 1 - MOV Characteristic

An MOV also features non-ohmic current-voltage characteristics similar to that of a diode. In contrast to a diode, however, an MOV has the same characteristic for both directions of traversing current.

As the current increases across an MOV, so does the clamping voltage as shown in the Figure 2 graph below. MOVs are traditionally assigned a nominal rating at the voltage where the current achieves a 1 milliampere level. At voltages below this rating, the currents are considered leakage currents. Above this voltage rating, the MOV is in a protecting state and exhibiting a clamping voltage. As can be seen in Figure 2, increasing currents result in increasing clamping voltages.

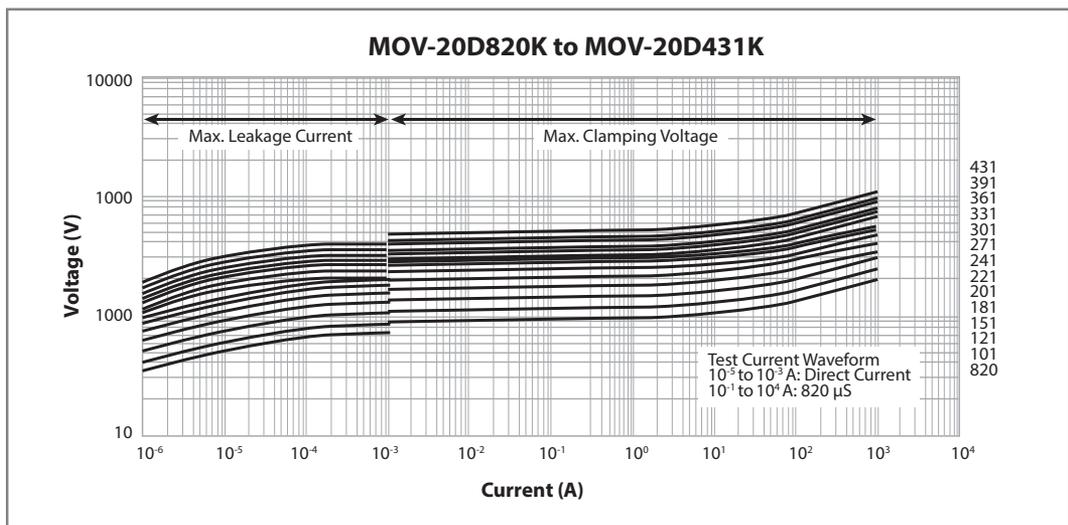


Figure 2 - MOV-20D820K to MOV-20D431K Clamping Voltage



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MOV FAILURE MODES

MOVs typically conduct a small amount of leakage current even at applied voltages that are well below their nominal threshold voltage. If an MOV is subjected to surges beyond its rating, permanent damage can occur that causes the leakage current to increase. In some applications, leakage currents of only a few milliamperes can present a shock hazard.

Furthermore, if this leakage current becomes sufficiently high, self-heating will occur inside the MOV. As noted earlier, the instantaneous power dissipated in an MOV is the applied voltage multiplied by the current across the MOV. When an MOV is connected continuously across the AC mains, this self-heating can create positive feedback where higher leakage current leads to higher self-heating, which in turn leads to even higher leakage current.

Subsequent surges can further accelerate this failure. At some point the MOV will go into a thermal runaway mode that generates considerable heat and destroys the MOV. In some situations, the heat produced by the MOV can become a Potential Ignition Source (PIS) and cause nearby ignitable materials to catch fire.

ALTERNATIVES TO MOVs

Very few surge protection components can handle the high surge currents (several thousand amps) that are typically experienced on AC mains lines. In addition to MOVs, another common surge suppression component that can survive very high surge currents is the [Gas Discharge Tube \(GDT\)](#).

GDTs achieve their impressive current handling ability by having an abrupt trigger voltage at which they switch into a conducting state that functions almost as a short circuit. This is sometimes referred to as a “crowbar” characteristic. Note that when a two-terminal surge protection component is conducting, the instantaneous power dissipation in the component is:

$$\text{Power Dissipation} = (\text{voltage across component}) \times (\text{current passing through component})$$

So, unlike an MOV, the GDT tolerates large surge currents because, when triggered, the voltage across it drops to a low value (approximately 10 V, often referred to as “arc voltage”). This keeps the instantaneous power dissipation low. The result is that for the same surge current capability, a GDT can be physically smaller than the corresponding MOV. For example, if an MOV clamps the voltage to 900 V at 1000 A, it is dissipating 900 kW while a GDT, which only has 10 V drop, dissipates only 10 kW.



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ALTERNATIVES TO MOVs (Continued)

Figure 3 shows a comparison between MOV and GDT voltage during the surge current.

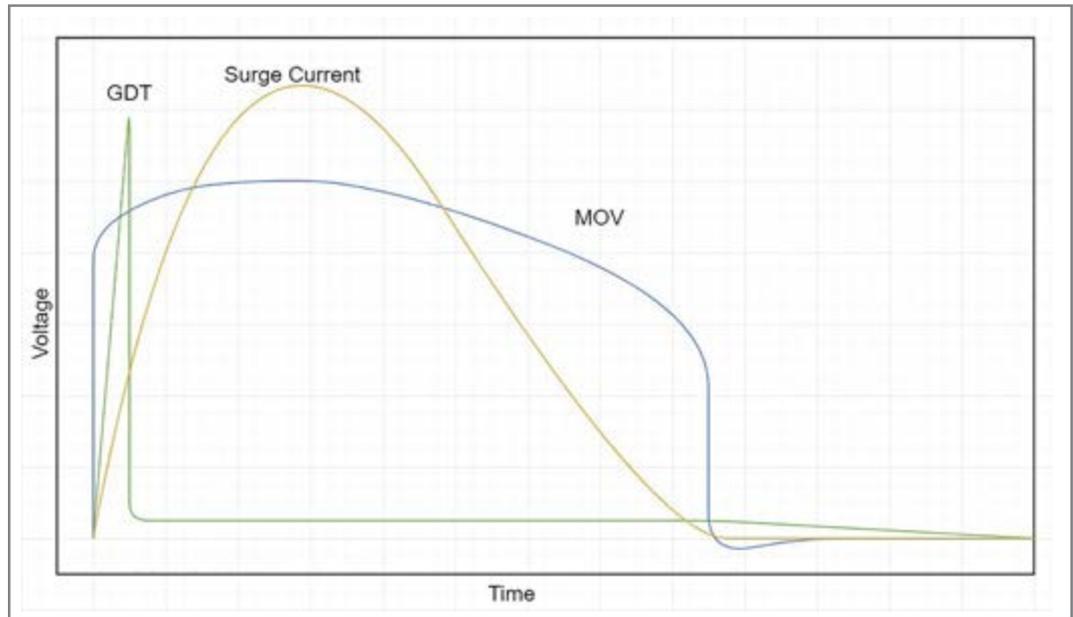
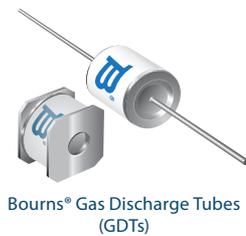


Figure 3 - Comparison Between MOV and GDT Voltage During the Surge Current

Figure 4 offers a side-by-side comparison between a typical MOV and GDT with equivalent surge ratings. Both components are rated for a nominal current of 5 kA.



Figure 4 - MOV & GDT

Once triggered into the conducting state, a GDT requires the current to drop to nearly zero to reset the GDT to the off condition. For applied 60 Hz AC waveforms, the current drops to zero twice per cycle, corresponding to every 8.3 ms, so this would appear to provide the required turn-off opportunity. Unfortunately, if an overvoltage condition keeps a GDT in the conducting state for more than a few seconds, the accumulated heat in the GDT will prevent it from turning off in response to the very short zero crossings of a 60 Hz AC mains waveform. So, GDTs by themselves are not adequate substitutes for MOVs connected to the AC mains.

Bourns® IsoMOV™ Hybrid Protectors



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance



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KEY MOV ELECTRICAL PARAMETERS

While the general behavior of an MOV resembles that of two back-to-back avalanche diodes, the amount of surge current that an MOV can survive is considerably higher. An MOV datasheet typically specifies the voltage that corresponds to the maximum AC_{rms} voltage (also known as Maximum Continuous Operating Voltage – MCOV) that the MOV will withstand continuously without conducting significant current. Both IEC 60950-1 and UL/IEC 62368-1 require that the rated voltage of the MOV be at least 125 % of the rated voltage of the equipment. So, for a 240 V_{rms} mains circuit, the rated voltage of the MOV must be at least 300 V_{rms} .

At the normal applied mains voltages of 240 V_{rms} , an MOV rated at 300 V_{rms} will conduct less than 1 mA. However, if a surge is applied across the MOV, the MOV will conduct far more current and will limit the surge to typically less than 1 kV. Given that lightning surges on the AC mains can exceed 6 kV and can have peak currents that exceed 3000 A, an MOV's ability to limit such surges to less than 1 kV without damage is a very helpful first line of defense for surge protection.

When tested with a standard 8/20 μs impulse surge, the small MOV (10 mm) in Figure 5 can handle 100 surges of 1000 A without incurring damage, while the large MOV (20 mm) can handle 100 surges of 3000 A. Furthermore, when tested with a 3000 A surge, the small MOV will limit the surge voltage to 550 V, while the large one will limit the surge voltage to 450 V. Below is a graph showing clamping voltage relative to surge current between the 10 mm vs. 20 mm size of the same voltage MOVs.

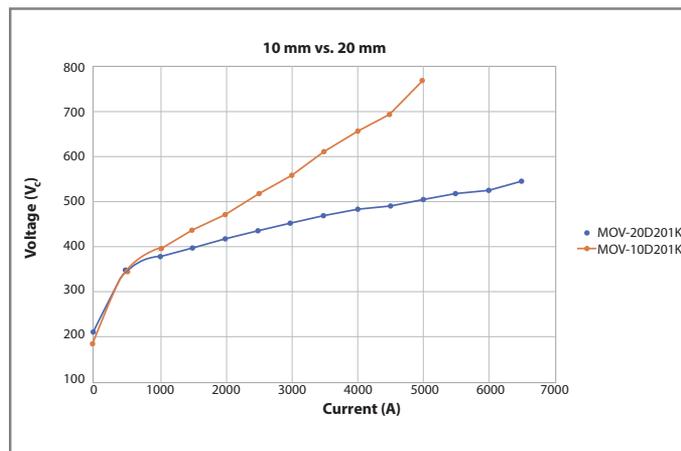


Figure 5 - Comparison Between 10 mm and 20 mm MOVs

So, in addition to selecting MOVs with suitable turn-on thresholds, designers must also consider both the size and number of surges to which the MOV is likely to be subjected over its lifetime. While a physically smaller 300 V_{rms} MOV is generally less expensive than a larger one, it may not hold up as well in real-world applications. Some of the requirements and tests in UL/IEC 62368-1 are specifically developed to help designers from using undersized MOVs. To comply with the surge tolerance requirements in UL/IEC 62368-1 (10 positives and 10 negatives at 3 kA), most AC mains applications will require an MOV with a minimum disc diameter of 14 mm.

For tips on selecting the right MOV, please refer to the available white paper "[Tips on Selecting the Right MOV Surge Suppressor](#)" here:

<https://www.bourns.com/docs/technical-documents/technical-library/varistors/bourns-tips-on-selecting-the-right-mov-surge-suppressor-white-paper.pdf>



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance

REQUIREMENTS THAT ADDRESS ELECTRIC SHOCK HAZARDS



Bourns® Metal Oxide Varistors (MOVs)



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Figure 6 - Cheater Adapter

Type A plugs can have either two or three contact pins. The 2-pin version only connects to the AC mains and is used when the equipment does not require a ground connection to ensure safety. The 3-pin version adds a ground pin for connection to earth ground. Often the ground connection for such equipment consists solely of this third pin on the AC mains plug.

Sometimes the ground connection in the wall outlet is not properly connected to earth ground. Moreover, some users will use a “cheater adapter” (Figure 6) to connect a 3-prong plug to a wall outlet that accepts only 2-prong plugs. For these reasons, the earth ground connection achieved with a Pluggable Type A plug is not considered completely reliable.

As noted previously, if an MOV is connected from the AC mains to protective earth, the leakage current through the MOV will simply flow to protective earth. However, if the intended earth connection is not made, steps need to be taken to prevent possible electric shock to users when they touch conductive parts that are supposed to be grounded.

For Pluggable Type A equipment, the most common solution for preventing MOV leakage current from becoming an electric shock hazard is to place one or more GDT in series with the MOV. A GDT has almost no leakage current until the applied voltage gets close to the GDT turn-on voltage. If the GDT has a nominal turn-on voltage of $300 V_{rms}$, no significant leakage current will flow for an applied AC mains voltage of $240 V_{rms}$.

Offering a space-saving, more efficient solution, Bourns has designed two new hybrid surge protection components: the GMOV™ and IsoMOV™ protectors. Both hybrid designs integrate a GDT and an MOV into a single component that can serve as drop-in replacements for an existing MOV footprint. The GMOV™ protector combines two discrete components, while the IsoMOV™ protector offers an innovative new design approach that combines the two technology functions into one fully integrated component. Because of the new patent pending design of the metal oxide technology, the IsoMOV™ component also has a higher current rating for the same size. For example, a 14 mm size IsoMOV™ protector (which has 5 kA nominal current rating) is equivalent to a 20 mm size GMOV™ protector or MOV.



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance

REQUIREMENTS THAT ADDRESS ELECTRIC SHOCK HAZARDS (Continued)

The Bourns® GMOV™ or IsoMOV™ hybrid overvoltage protectors provide an optimal solution for the application in Figure 7:

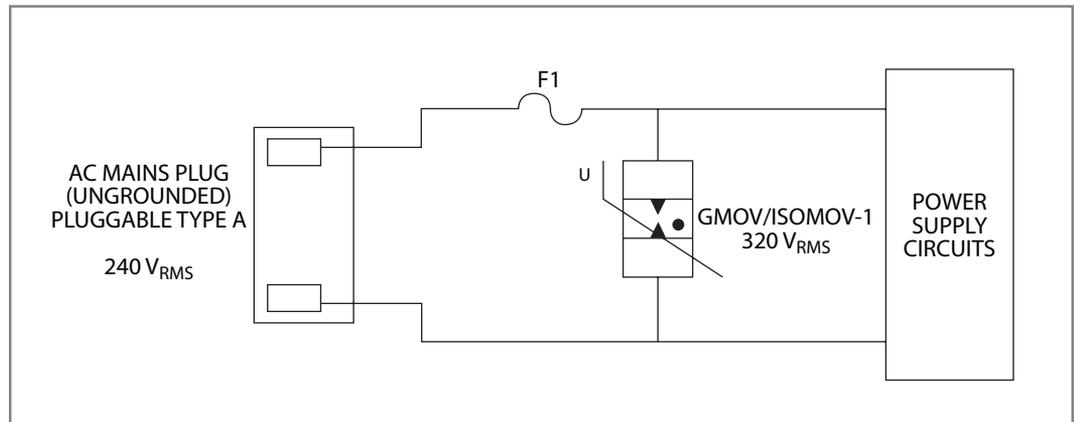


Figure 7 - Optimal Solution Schematic

Figure 8 is an equivalent schematic to Figure 7 for comparison:

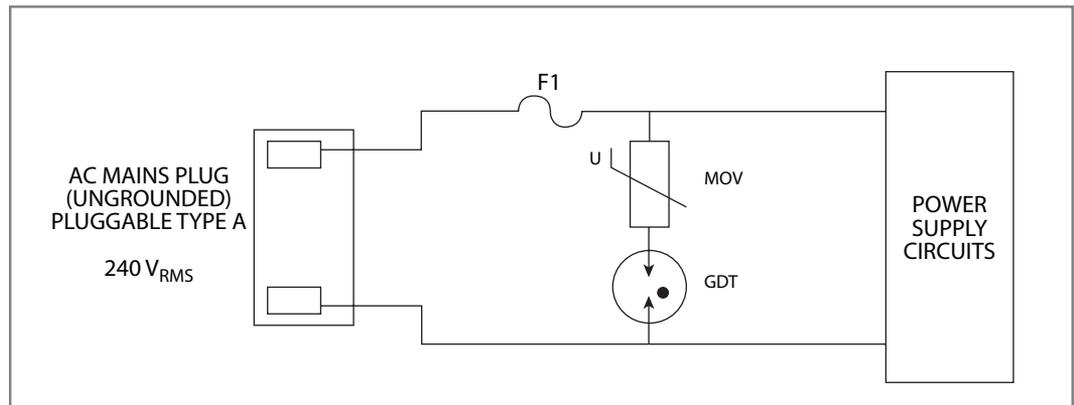


Figure 8 - Equivalent Schematic to Figure 7 for Comparison



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance



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REQUIREMENTS THAT ADDRESS ELECTRIC SHOCK HAZARDS (Continued)

The circuit in Figure 7 shows that by using a GMOV™ or IsoMOV™ hybrid overvoltage protector, the risk of fire is low because the turn-on threshold is far above the normal AC mains voltage. Using a typical GDT and MOV in series will have a turn-on voltage approximately 60 % to 90 % of the total voltage of the two components combined. For example, a 300 V GDT + 300 V MOV is 600 V, but the turn-on could be anywhere between 360 V to 540 V. Because the bias voltage is being blocked by the GDT and there is no constant voltage across the MOV, the degradation and leakage issue will be virtually non-existent.

For limiting the risk of fire, some standards will exempt an MOV that has a turn-on threshold far above the normal AC mains voltage. The rationale is that, if the likelihood of the surge damage to the MOV is low, the risk of fire is adequately addressed. In UL/IEC 62368-1, Table G.10 acknowledges this by stating that no testing is required if MCOV > 2xVr. The beauty of the GDT+MOV combination is that the turn-on threshold behaves like a higher voltage MOV but has the same clamping voltage of a lower voltage MOV.

One way to comply with UL/IEC 62368-1 is to add protection from Line (L) and/or Neutral (N) to Protected Earth (PE) as shown in this example (Figure 9):

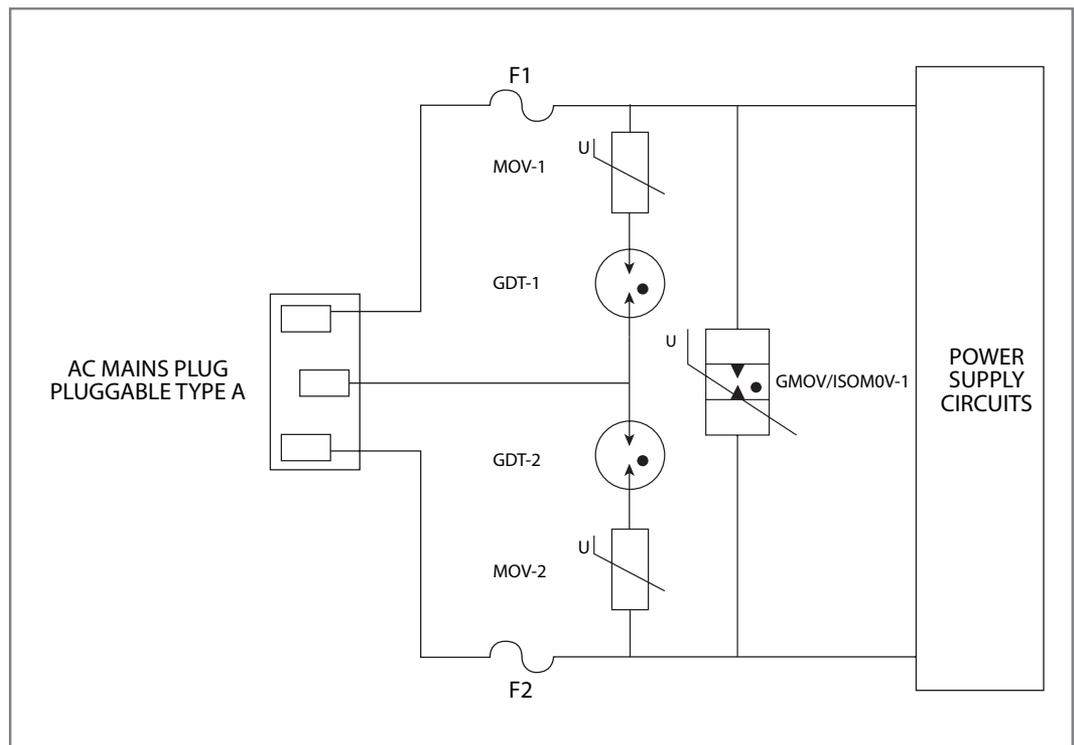


Figure 9 - Schematic Showing Compliance with UL/IEC 62368-1



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance

REQUIREMENTS THAT ADDRESS ELECTRIC SHOCK HAZARDS (Continued)

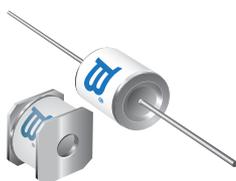
Under Section 5.4.9.1 of UL/IEC 62368-1, the test voltage is determined by the highest value of three (3) testing methods (withstand voltage, working voltage, and temporary voltage). The highest peak value of these three voltages becomes the GDT test voltage, which is applied as either a peak AC or DC voltage. For example, 120 VAC mains results in test voltage values of 1.5 kV peak (overvoltage category II), 243 V peak and 2 kV peak, respectively.

Similarly, 230 VAC mains gives test voltage values of 2.5 kV peak (overvoltage category II), 465 V peak, and 2.5 kV peak. Since there can be no insulation breakdown (also known as sparkover for GDTs) during these tests, the minimum GDT sparkover voltage needs to be 2.5 kV for 120 VAC and 3 kV for 230 VAC. Adding these GDTs in series with the MOVs that are connected between AC mains and protected earth means that there can be no conduction or protection at voltage levels below 1.4 kVAC or 1.7 kVAC, depending on AC mains voltage. The 1.4 kVAC and 1.7 kVAC values are calculated from the lower limit of the 2.5 kV GDT and 3 kV GDT, respectively. GDTs have 20 % tolerance and are typically rated in DC, so the lower limit of 2.5 kVDC is 1.98 kVDC and 3 kVDC is 2.4 kVDC. The peak voltage of 1.4 kVAC is 1.98 kVp while 1.7 kVAC is 2.4 kVp.

Currently, Bourns does not offer a GMOV™ or IsoMOV™ component with the high voltage specification (> 1 kV) to address the requirement between line-to-earth and neutral-to-earth. Therefore, discrete components must be used, as shown in Figure 9.



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CLAUSE G.8 REVIEW

When it comes to UL/IEC 62368-1 compliance for MOVs, the standard specifically states that the varistor shall comply with Clause G.8. The general requirements (G.8.1) of this clause specifies MCOV to be at least 1.25 times the equipment rated voltage (V_r) or at least 1.25 times the upper voltage of equipment rated voltage range. For equipment nominally rated at 230 VAC, the minimum MCOV is 288 VAC. If the equipment has a voltage range, for example, 85 VAC to 250 VAC, then the minimum MCOV is 313 VAC.

Furthermore, Clause G.8.2 emphasizes that the MOV shall be regarded as a Potential Ignition Source (PIS) and that steps should be taken to reduce the likelihood of ignition and prevent fire spread.

In addition, the requirements in Clause G.8.2.2 are necessary to be applied to either an MOV or an overvoltage protective circuit containing an MOV that is connected across the AC mains (L to N), line to protective earth (L to PE), or neutral to protective earth (N to PE). The test is to step up the power in the MOV progressively until the MOV fails. The test voltage used is based on the value of 2 times V_r and defines the respective short-circuit current via an inline resistor. The short-circuit current starts at 0.125 A, 0.5 A, 1 A, 2 A, 4A, etc. Basically, the current is doubled for each step. Testing is terminated when the circuit opens (a fuse opens) or when the failure event occurs, such as a disconnecter operation (i.e., thermally protected MOV).

This clause does not address the disconnecter mechanism for testing at a higher breaking current level where there may be substantial operational lag time and currents that exceed the disconnecter capability. A voltage source of 2 times V_r limits the ability of the circuit to induce MOV failure. Selecting an MOV with MCOV of 2 times V_r means there can never be any substantial current conduction and the test becomes inconsequential.

In UL/IEC 62368-1, Table G.10 acknowledges this by stating that no testing is required if MCOV is 2 times V_r . For testing a single MOV, a source of 2 times MCOV would ensure the MOV could be exercised to failure. The protective circuit with the GDT in series will prevent current flow, making the test inconsequential. Even though tests like Clause G8.2.2 have led to the creation of the thermally protected MOV, it is mainly useful for connection across the AC mains and is unnecessary when the MOV is in series with a high voltage GDT.

Testing required to meet Clause G.8.2.3 for Temporary Overvoltage (TOV) is only applied between L to PE or N to PE. Note there is not a test for L to N terminals. Due to the high voltage GDT sparkover, the 2.5 kV overvoltage category II test could be inconsequential as the GDT will not sparkover.



Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance

IN SUMMARY

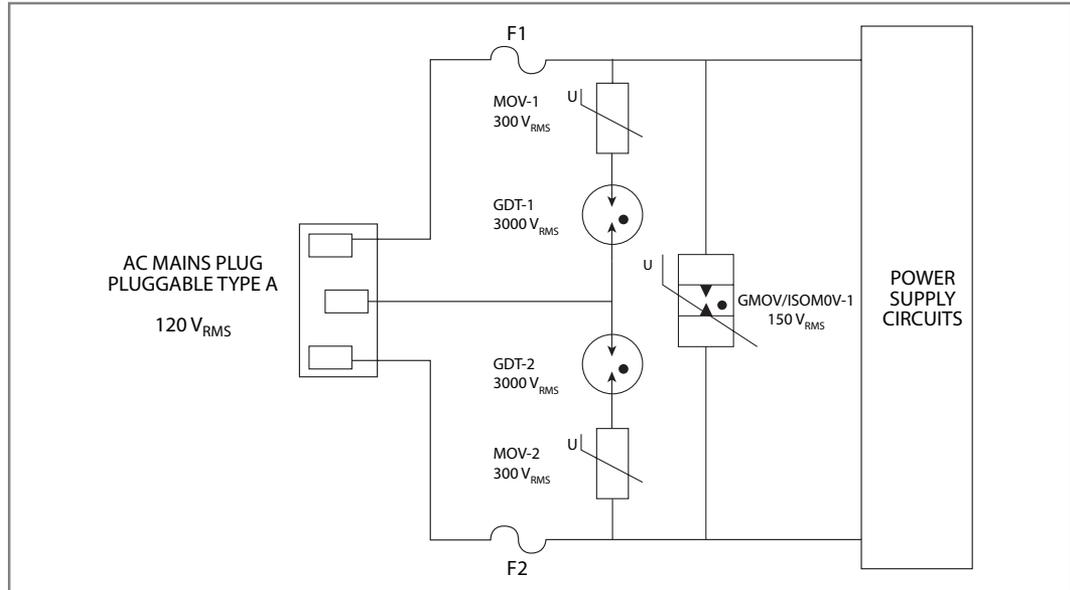
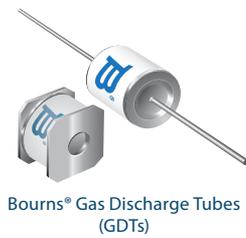


Figure 10 - For 120 VAC Protection

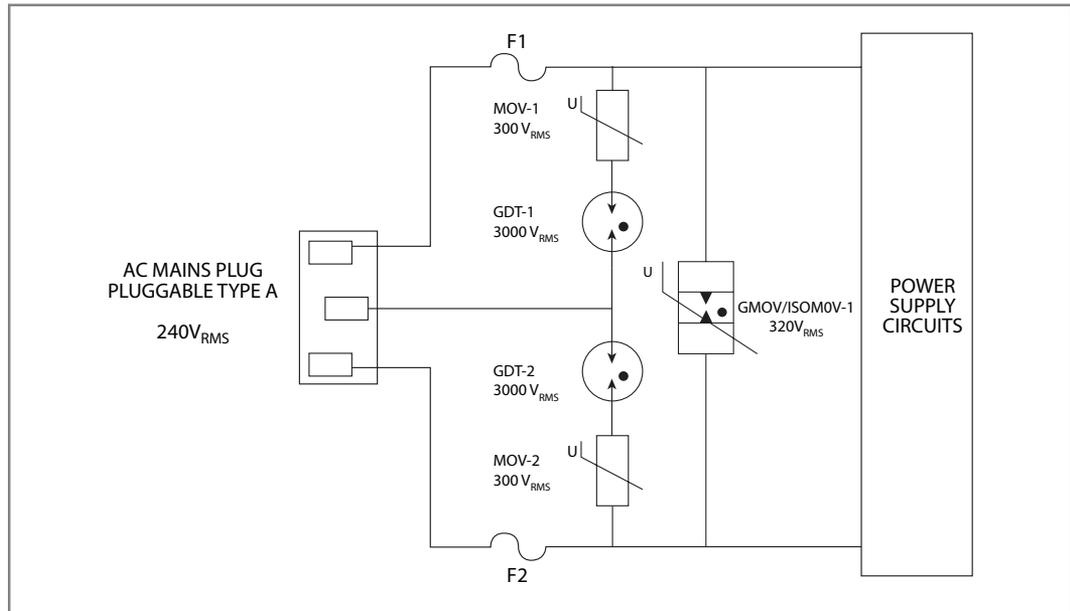


Figure 11 - For 240 VAC Protection (or Voltage Range Equipment up to 240 VAC)

*The above circuit protection solutions reflect Bourns' interpretation of the standard. Readers should review the standard independently and make their own conclusions regarding the requirements of the standard.



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IN SUMMARY (Continued)

The goal of the UL/IEC 62368-1 standard is to address the possibility that overstressed MOVs could create an electrical shock hazard as well as possibly causing a fire. The recommendation in the UL/IEC standard is to add a series GDT to minimize these potential issues. With the additional high voltage GDT in series, the Varistor Overload (G.8.2.2) and Temporary Over Voltage (TOV) (G.8.2.3) may become inconsequential as the testing voltage requirement is below the GDT's breakdown voltage*. Nevertheless, testing should still be conducted to ensure compliance with the standard requirements and, in particular, those outlined in sections G.8.2.2 and G.8.2.3. If the Bourns interpretation of the standard is correct, then the diagram of a surge protection solution shown on the previous page would appear to be adequate to meet its requirements. However, Bourns encourages readers to review the standard for themselves and reach their own conclusions about the requirements of the standard.

REFERENCE

Bourns® MOVs can be found here:

<https://www.bourns.com/products/circuit-protection/varistor-products/through-hole>

Recommended Model: CVQ300K14 or MOV-14D471K

Bourns® GDTs can be found here:

[https://www.bourns.com/products/circuit-protection/gas-discharge-tube-\(gdt\)-surge-arrestors/2-electrode-gdts/high-voltage-series](https://www.bourns.com/products/circuit-protection/gas-discharge-tube-(gdt)-surge-arrestors/2-electrode-gdts/high-voltage-series)

Recommended Model: 2093-300-SM or SA2-3000-Cxx-STD

Bourns® GMOV™ protectors can be found here:

<https://www.bourns.com/products/circuit-protection/varistor-products/hybrid>

Recommended Model: GMOV-14D151K (for 120 VAC) or GMOV-14D321K (for 240 VAC)

Bourns® IsoMOV™ protectors can be found here:

<https://www.bourns.com/products/circuit-protection/varistor-products/hybrid>

Recommended Model: ISOM3-175 (for 120 VAC) or ISOM3-320 (for 240 VAC)

**The circuit protection solutions shown on the previous page reflect Bourns' interpretation of the standard. Readers should review the standard independently and make their own conclusions regarding the requirements of the standard.*



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BOURNS®

Americas: Tel +1-951 781-5500
Email americus@bourns.com

EMEA: Tel +36 88 885 877
Email eurocus@bourns.com

Asia-Pacific: Tel +886-2 256 241 17
Email asiacus@bourns.com